TITLE: PROCEDURES FOR DETERMINING THE SWELLING PRESSURE OF COMPACTED BENTONITE

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PROCEDURES FOR DETERMINING THE SWELLING PRESSURE OF COMPACTED BENTONITE

1. OBJECTIVES AND OUTLINE OF PROCEDURE

The objective of this test is to determine the swelling pressure of compacted bentonite. The test is conducted on a cylindrical sample of compacted bentonite installed in a universal consolidometer. The sample is approximately 2.5" (12.7 cm) in diameter and about 1" (2.5 cm) in length. The test is conducted by establishing an axial confining (load) pressure to balance the swelling pressure created by injecting fluid into the bentonite sample. When the axial confining pressure equals the swelling pressure in the sample, the sample maintains constant length. At the equilibrium, the applied confining pressure is the swelling pressure of the bentonite sample. The confining pressures and fluid injection pressure (back pressure) are continually monitored, recorded and adjusted as necessary to maintain the desired test parameters.

2. Quality Assurance

All testing activities will comply with the SNL WIPP quality assurance program, and will be documented in scientific notebooks and on the test report form included in the Appendix. Results of testing as documented in notebook shall be reviewed by the UNR PI or designee (Dated and initialed).

3. Records

All documentation developed during the testing activities should be identified as a QA record and submitted to the principal investigator for review.

4. Calibration

All pressure transducers, pressure gages, thermocouples, LVDTs, temperature probes and data acquisition systems used in the Universal Consolidometer shall be calibrated using standards traceable to NIST or/and intrinsic standard recognized by NIST. The balance used to weigh samples and the compact compression machine should have a valid calibration. Standard weights should be used for accuracy checking (see WIPP Procedure 162) each time the balance is used. Record S/N's of scale, pressure gages, and transducers and standards, plus results of the checks in the scientific notebooks. All calibration documentation shall be submitted to the QA department.

5. Apparatus

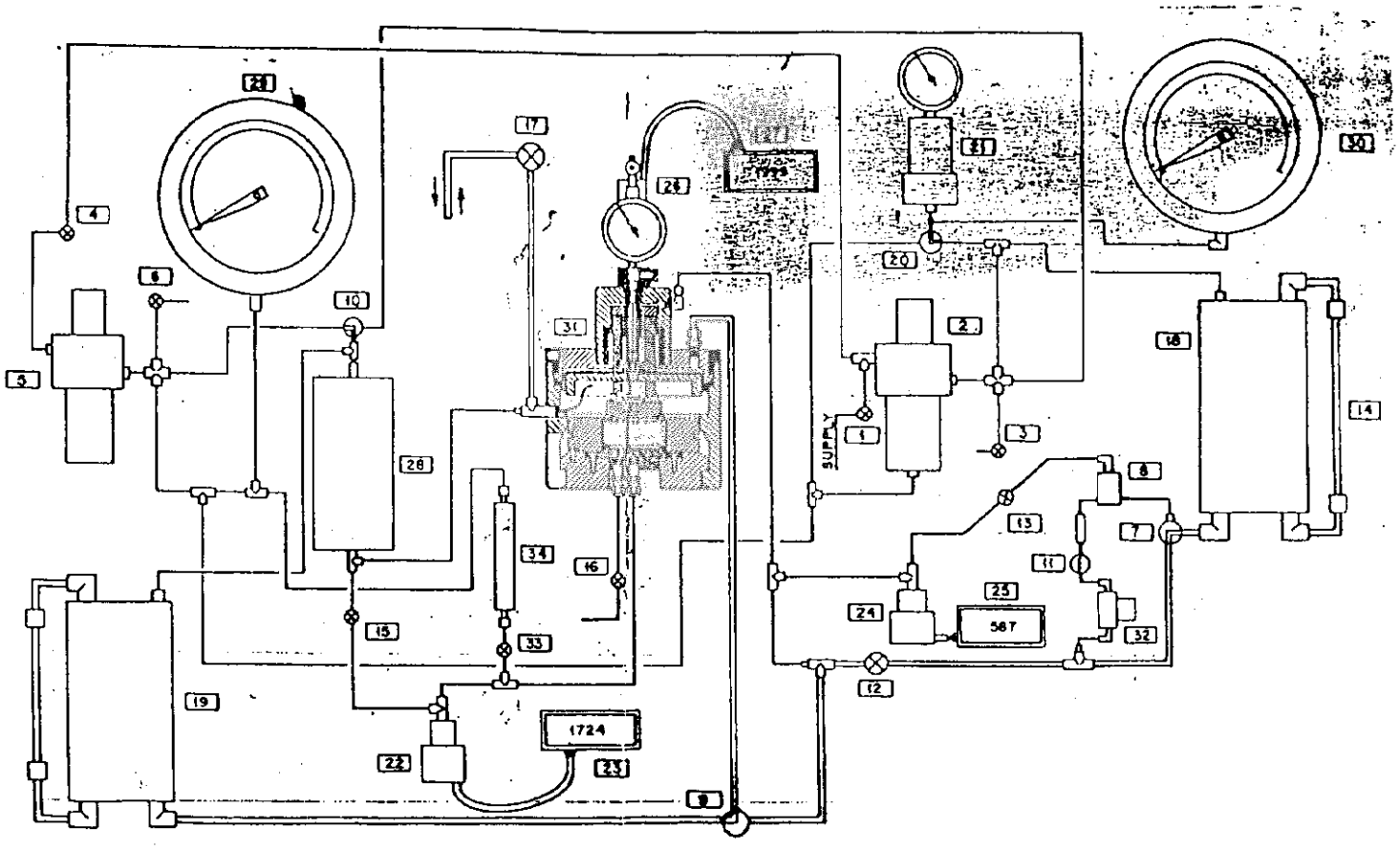
1) Universal Consolidometer - includes the following components:
   - Pressure gages

- Pressure transducers (one for load pressure, one for back pressure)
- Thermometer
- Thermocouples
- Fluid Reservoirs
- Pressure Regulators (load pressure, back pressure)
- Dial gage indicator
- Linear Variable Displacement Transducer (LVDT)

2) Nitrogen gas tanks
3) Steel disks
4) Porous stone disks

Substitute Items may be used as long as their accuracy is equal to or greater than the item it replaces. Before continuing make sure all items appear to be in good working order.

6. MATERIALS



Universal Consolidometer Components:

1. Supply Pressure Valve (Load)
2. Load Pressure Regulator
3. Load Pressure Vent Valve
4. Supply back Pressure Valve
5. Back Pressure Regulator
6. Back Pressure Vent Valve
7. Mode Selector Valve (Manual-Automatic)
8. Flow Regulator
9. Load Range Selector Valve
10. Permeability Selector Valve
11. Strain Rate Control Valve
12. Terminal Valve
13. Feedback Valve
14. Sight Tube
15. Pore Pressure Transducer DEAIR Valve (Also as Equalizer)
16. Bottom Saturation Valve
17. Top Saturation Valve
18. High Load Pressure Reservoir
19. Low Load Pressure Reservoir
20. Selector Valve for Pressure Cartridge
21. Pressure Cartridge with Dial Indicator
22. Pore Pressure Transducer
23. Pore Pressure DPI
24. Load Pressure Transducer
25. Load Pressure DPI
26. LVDT Strain Indicator Dial Assembly
27. LVDT DPI
28. Saturation Water Reservoir
29. Back Pressure Gauge
30. Load Pressure Test Gauge
31. Loading Dome
32. Solenoid Valve
33. Permeability Valve
34. Permeability Burette
35. Selector Switch (Auto - Manual)
36. Gradient-Strain Selector Switch

Figure 1 Control Panel for the Universal Consolidometer Component Numbering (from Geotest, undated)

7. TEST PROCEDURE

7.0. Sample preparation

See WIPP Procedure 536.

7.1. Test Preparation

1) Check that the valves are in the following positions: No. 1, 4, 12, 15, and 33 are closed. No. 3, 6, 16, and 17 are open.
2) Selector valve No. 7 is in the Manual position.
3) Selector valve No. 9 in High Pressure and selector switch in Manual position.
4) Selector valve No. 20 in Load Pressure position.
5. Selector valve No. 10 in Off position.
6) Turn on main power switch - When the switch is turned ON, all three panel meters should display a readings. Let the system warmup a minimum of 30 minutes before initiating testing.
7) Deair the dome as follows:
   a. Check that supply pressure is available to the unit. This is shown by the supply gauge located on the upper left side of the test panel.
   b. Axial strain dial indicator assembly is removed from the dome.
   c. Close vent valve No. 3 and open supply valve No. 1.
   d. Adjust load pressure regulator No. 2 until it indicates approximately 40 kPa.
   e. Remove the dome from the base and place terminal valve No. 12 in the open position.
   f. Observe that the loading disc moves, continue until the disc contacts the ledge on the inside of the dome.
   g. Close supply valve No. 1 and open vent valve No. 3.
   h. Turn the dome upside down and push the loading disc inward while rotating the dome to the upright position. Push the loading disc resting on the elevated circular platform so that the weight of the dome will be pushing the loading disc upward.

      NOTE: It is very important to watch the liquid level in the sight tube of the high pressure load reservoir.

   i. On top of the sight tube, switch valve No. 9 into the low position.
   j. Let the loading disc retract as fast as it will, then switch valve No. 9 back into the high load position.

      NOTE: If too much fluid is forced into the reservoir it will enter through the airlines into the load pressure tubing, you will then have to repeat steps a. through j.

   l. When the dome has been properly deaired, close terminal valve No. 12.

      NOTE: During this part of the procedure the water level in the high load reservoir sight tube should be about 2 cm or more from the bottom nut when the loading disc is in contact with the ledge.

7.2. Preparing and Installing Sample

7.2.1 Bentonite samples will be prepared as described in Technical Operating Procedure 536.

7.2.2 Install the sample into the universal consolidometer as follows:

1) Push the spacer block into the shoe from the cutting edge side and shave off the excess sample on the flat end side of the cutting shoe. Remove the space block and obtain the weight of the sample which is now exactly 1" in length.
2) Place a clean consolidometer ring into the base (either regular or K-O type of O-ring). Push the slightly oiled O-ring down over the porous disk holder.
3) Check to ensure valve No. 16 is open.
4) Place the cutting shoe containing the sample into the recess of the consolidation ring.
5) Using the upper porous plate, transfer the sample from the cutting shoe into the consolidation ring. Remove the cutting shoe but leave the upper porous plate block on the sample.
6) Place the two part spherical spacers into the recess on top of the porous plate block.
7) Pick up the dome (the dome should be deaired and the loading disc should be retracted) and line up the bayonet lock properly, making sure that the bleed tubing I properly placed in the recess of the loading disc.
8) Push the dome down over the O-ring seal which is in the upper groove of the consolidation ring. Then rotate the dome until the bayonet locks are fully engaged.
9) Install the dial indicator assembly.
10) Check that valve No. 12 is closed.

7.2.3 Moving the Loading Disc to Contact the Sample

1) Check to ensure that selector valve No. 7 is in manual mode, and turn selector valve No. 9 into the low position. Close feedback valve No. 13.
2) Close load vent No. 3, then open load supply No. 1.
3) Set the load pressure regulator output to a value that causes the loading disc to move downward at a rate of approximately 0.02 mm per second.
4) Close terminal valve No. 12 and record the readings indicated on the load pressure panel meter.
5) Open terminal valve No. 12 slightly to allow loading disc to move down slowly. [total movement will be approximately 2 mm]
6) When contact is made with the sample the reading on load pressure panel meter will start to increase. Close the terminal valve No. 12 and record the reading on the axial strain panel meter.
7) Turn load range selector valve No. 9 into high range. Slightly open terminal valve No. 12 to restore reading of axial strain panel meter.
8) Reduce load pressure to approximately 0 kPa (0 psi).
9. Record the readings indicated on the load pressure meter and axial strain meter.

7.2.4 Introducing Saturation Fluid

Note: Major chemical elements of the saturation fluid should be analyzed, or such data are available before or after testing. The pH of the fluid should be measured or should be available.

1) Connect the desired fluid to the end of tubing No. 17 (the free end of tubing leading to valve No. 17) Note: If K-O ring is used turn on electronic system and put selector switch into manual position and balance null indicator.
2) Open valve No. 17 to and fill the Lucite reservoir until approximately half full. Then close valve No. 17. This will take a while because of the relatively large volume of the saturation area.

Note: You may obtain the swelling pressure in kPa - if any - by reading the change on the load pressure DPI and multiplying it by (5.3). This will be true if terminal valve No 12. and feedback valve No 13 are closed, dome is well deaired and bayonet lock claws are tight against each other. Also the terminal valve might have to be opened slightly and temporarily just enough to keep strain at zero. The multiplier of 5.3 is for 2.5" diameter sample. (For other sizes find the multiplier by dividing 26 with the crossectional area of sample in square inches.)

3) Be sure to record the temperature onto the data form.

7.2.5 Applying Back Pressure

1) Open valve No. 12, 15, 16, 17, and close valve No. 33.
2) Check to ensure the back pressure regulator has been set to minimum output (turn counter clockwise as far as it goes with little force), and then close vent valve No. 6.
3) Slowly open supply No. 4. As soon as valve No. 4 is opened, the back pressure gauge will show a reading (approx. 20 kPa); the load pressure test gauge indicator will show a responding pressure increase; water will move due to movement of the dome. Take reading, before and after movement.
4) Open valve No. 16 and then close valve No. 16 to deair the pore pressure circuit. Keep doing this until no more air bubbles are observed in deair tube. Then keep valve No. 16 closed.
5) Open permeability valve No. 33 to let water flow into the permeability burette. Inspect whether fluid appears in burette. Close valve No. 33.

7.3 Measure Swelling Pressure

7.3.1 Increase loading pressure to maintain initial sample length

Note: when sample swells, dial indicator reading increases and LVDT reading decreases. The loading pressure to force the sample back to the initial length is the swelling pressure at that time. When swell stops, increase the back pressure until the sample is fully saturated and no more swelling pressure increase takes place.

1) Make sure terminal valve No. 12 is open.
2) Raise the load pressure regulator output slowly to such a value that the dial gage indicator and the LVDT display show the initial value of the sample length.
3) Record date, time, load pressure, back pressure, room temperature, dial gage reading and LVDT reading on the report form in the appendix. If a data acquisition system is also used, record these parameters in a specified, unique named data file.
4) Maintain loading pressure and reduce the supply pressure to equal to or less than the loading pressure.
5) Repeat steps 1 to 4 regularly when sample length increases.

7.3.2 Increase back pressure to maintain saturation front forward until the sample is fully saturated

Follow steps in 7.2.5. Apply back pressure to increase the fluid injection pressure. Record parameters listed in step 3 in 7.3.1. on the report form. Assume the sample is fully saturated, if fluid appears in the permeability burette.

7.4 Termination of the Test

1). Reduce load pressure regulator output to 20 kPa above back pressure.
2). Open valve No. 15.
3). Reduce back pressure to minimum output.
4). Drain off saturation fluid.
5). Measure pH of out flow fluid and perform chemical analysis of the outflow fluid on selected samples.
6). Close supply pressure valve No. 4, and open vent No. 6.
7). Close supply pressure valve No. 1, and open vent valve No. 3.
8). Close terminal valve No. 12.
9). Remove axial strain indicator dial assembly.
10). Turn off electric power.
11). Rotate dome until bayonet blocks are free.
12). Insert a screwdriver into the groove on the side of consolidation ring and break loose the dome from the " O" ring seal.
13). Remove dome and spherical washers.
14). Place your thumbs on porous plate block and pull up on consolidation ring.
15). Remove sample.
16). Determine the moisture content of the sample.

8. TEST RESULT ANALYSIS

8.1 Computation and Data

Areas:
loading disc in high range =167.6 sq. cm.
loading disc in low range = 18.1 sq. cm.

sample 2.5" diameter = 4.91 sq. in = 31.67 sq. cm.

Load computation:

For load computation use the difference between applied load pressure as displayed by load pressure digital panel meter (load DPM) and back pressure. To take into account the effect of induced (excess) pore pressure, use the difference between the reading of pore pressure digital panel meter (pore pressure DPM) and back pressure.

Note that induced pore pressure can be measured only if valves No. 15, 16, and 33 are closed.

Load in high range in N = 16.435 (PL-PB)
Load in low range in N = 1.579 (PL-PB)

Pressure computation:

High range pressure on 2.5" diameter sample in kPa = 5.29 (PL-PB)

low range pressure on 2.5" diameter sample in kPa = 0.571 (PL-PB)
induced pore pressure = reading of the pore pressure DPM-BP on Test gauge.

K-O valve = 5.29(PL-PB) over (PK-PB) high range only.

Where PL is load pressure panel meter reading,
PK is K-O panel meter reading,
PB is back pressure test gauge reading.

Pressure cartridge with 0.01 mm dial indicator: 117 division =100 kPa.

8.2 Analysis

Tabulate and plot swelling pressure versus, testing time, sample density, brine concentration, the original sample moisture content at compaction, and other parameters which the research is interested in.

9. REFERENCES

Geotest Instrument Corp., undated, Operating Instructions for the Universal Consolidometer, Geotest Instrument Corp., Chicago, Illinois. 14 p.

APPENDIX

SWELLING PRESSURE TEST DATA SHEET

Sample Number (*SN*):	Apparatus: ☐ Consolidometer ☐ Odometer
Sample length (*L*):	Sample Diameter (*D*):
Permeant/saturation Fluid:	Sample density (ρ_s):
Sample Weight (g):	Fluid density (ρ):
Tested by:	Brine concentration (*M*) (if brine):

Date	Time	Displacement Reading		Pressures (kPa)		Temperature
(mm:dd:yy)	(hh:mm:ss)	Dial gage	LVDT	Swell/load	Injection	(°C)